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Twelve Roles and Three Types of Systems Engineering

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Twelve Roles and Three Types of Systems Engineering

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Software Productivity Consortium

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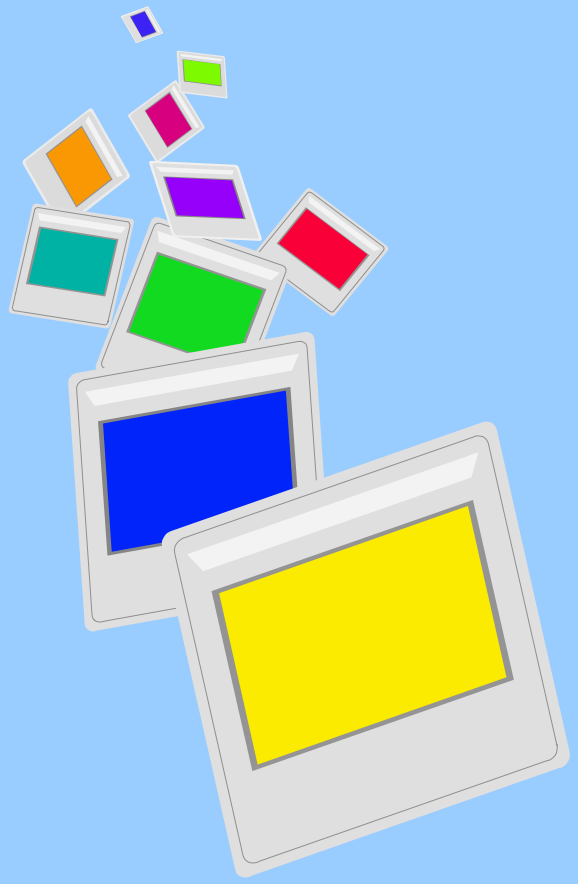
Agenda

- **Why Systems Engineering?**
- **Twelve Roles**
- **Three Types of Implementation**



What's New in Systems Engineering?

- **Systems are becoming far more software-intensive**
- **System complexity is increasing fast due to software complexity**
- **What's the same as it was, and what's different, and what should we do about it?**

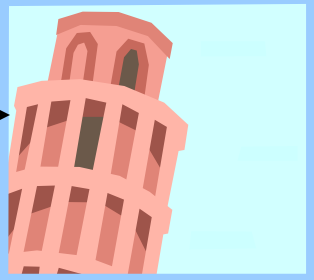
Original Reasons for Systems Engineering

Vasa, Sweden, 1628

- **Systems of pieces built by different subsystem groups didn't perform system functions**
  - **Often broke at the interfaces**

Photo from Dec 1999 Civil Engineering magazine

- **Problems emerged, and desired properties didn't, when subsystems designed independently were integrated**
- **Managers and chief engineers tended to pay attention to the areas in which they were skilled**



- **Developed systems were not usable**
- **Cost overruns, schedule delays, performance problems**

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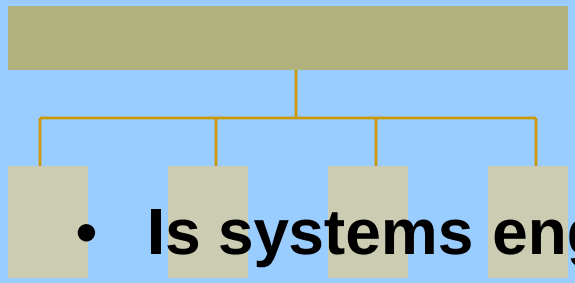
Concerns

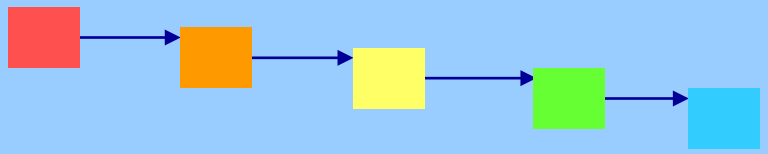
- Software is becoming the brain of most systems
  - But: Software developers are often not trained in engineering
  - And: Systems engineers rarely know software deeply
- Managers and politicians are not engineers… value of systems engineering is not clear
- What systems engineering is needed?
- How should systems engineering work for software?

Goals

- **Implement *interdisciplinary* engineering of systems**
  - **Reduce the risk and effects of system failures**
  - **Involve the right people at the right time**
  - **But we lack agreed-upon *operational definition* of "systems engineering" to use as rationale**
- ***INCOSE definition: "An interdisciplinary approach and means to enable the realization of successful systems"***
  - **Leaves open how it should be done**
  - **Inclusive and vague**

Can we answer these?



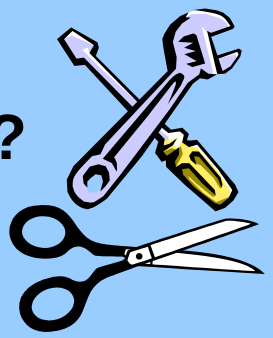


- **Is systems engineering the engineering of the top-level system, or a process?**
- **Are systems engineers specialists or generalists?**
- **Are systems engineers some people or all engineers?**

- **How well do standards and capability models describe systems engineering?**

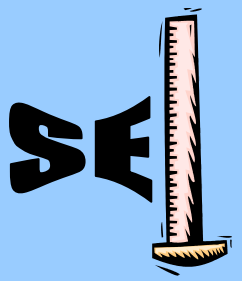
Can we answer these? (cont'd)

- What tools are needed for systems engineering?

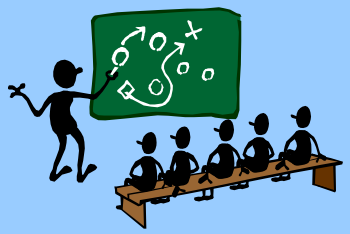


- What research should be done?

- How do you measure systems engineering?



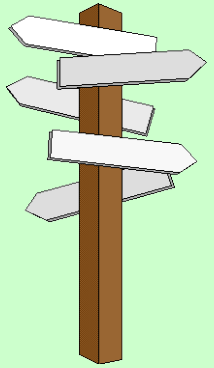
- How do you train people to do systems engineering?



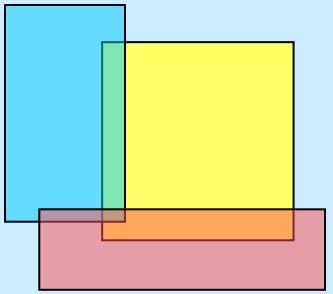
- How do you quantify the value of systems engineering?

Two Papers

- **"Twelve Systems Engineering Roles," 1996**
  - **Showed that INCOSE disagrees on what systems engineering is**
  - **Described twelve roles**
  - **Used as a definition of systems engineering**



- **"Three Types of System Engineering Implementation'" 2000**
  - **How systems engineering (and roles) are implemented**



At www.software.org at "Recent Papers"

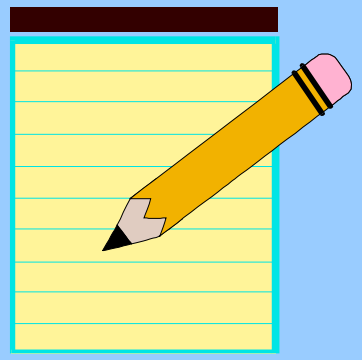
Approach of 12 Roles Paper

- **Describe roles considered part of systems engineering**
  - **Purpose: improve communication**
  - **Method: analyze INCOSE papers**

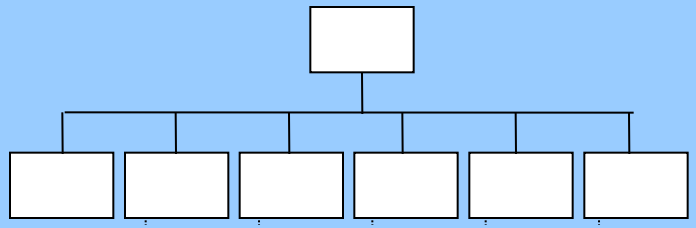
Twelve Systems Engineering Roles

- **RO** Requirements Owner
- **SD** System Designer
- **SA** System Analyst
- **VV** Validation and Verification Engineer
- **LO** Logistics/Operations Engineer
- **G** Glue among subsystems
- **CI** Customer Interface
- **TM** Technical Manager
- **IM** Information Manager
- **PE** Process Engineer
- **CO** Coordinator
- **CA** Classified Ads SE

Requirements Owner



- **Requirements Owner**
- **Requirements Manager, Allocater, Maintainer**
- **Specifications Writer or Owner**
- **Developer of Functional Architecture**
- **Developer of System and Subsystem Requirements From Customer Needs**



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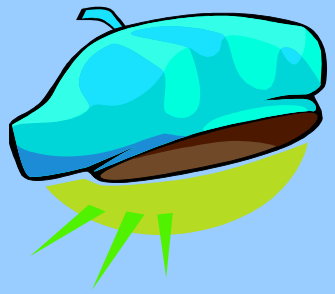
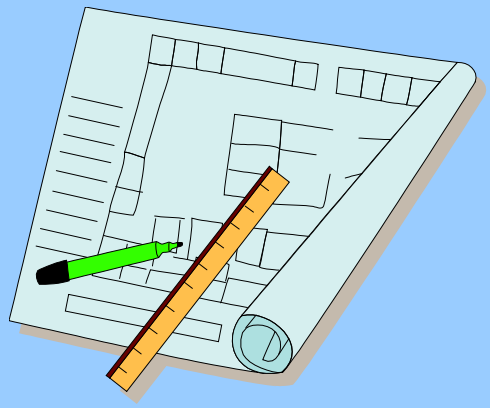


System Designer

- System Designer
- Owner of “System” Product
- Chief Engineer
- System Architect
- Developer of Design Architecture
- Specialty Engineer (Some, Such As Human-Computer Interface Designers)
- “Keepers of the Holy Vision” [Boehm 94]

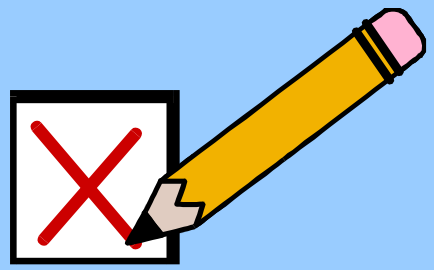


System Analyst

- System Analyst
- Performance Modeler
- Keeper of Technical Budgets
- System Modeler and Simulator
- Risk Modeler
- Specialty Engineer (Some, Such As Electromagnetic Compatibility Analysts)

Validation/Verification Engineer

- **Validation and Verification Engineer**
- **Test Engineer**
- **Test Planner**
- **Owner of System Test Program**
- **System Selloff Engineer**



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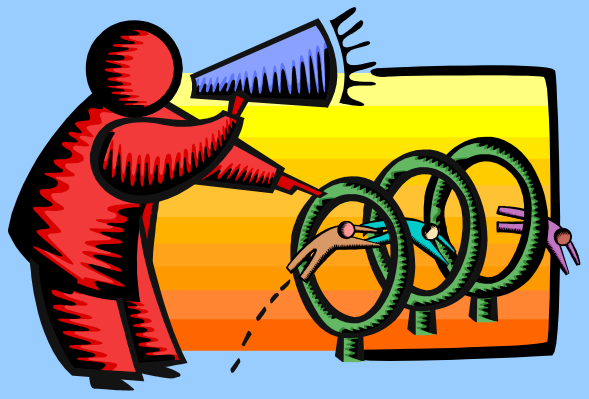
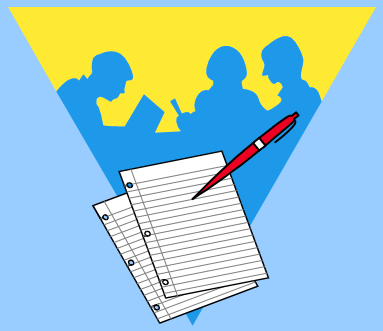
Logistics/Ops Engineer

- **Logistics, Operations, Maintenance, and Disposal Engineer**
- **Developer of Users' Manuals and Operator Training Materials**





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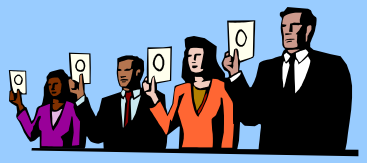
Glue Among Subsystems

- Owner of “Glue” Among Subsystems
- Seeker of Issues That Fall “in the Cracks”
- System Integrator
- Owner of Internal Interfaces
- Risk Identifier
- “Technical Conscience of the Program” [Fisher 92]

Customer Interface

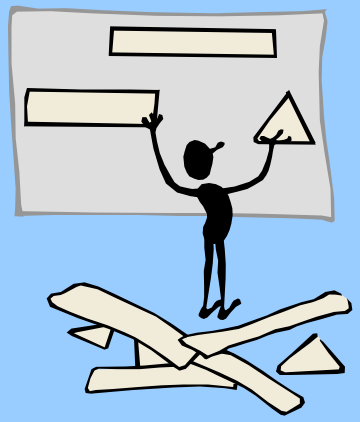
- Customer Interface
- Customer Advocate
- Customer Surrogate
- Customer Contact

- Marketing Interface
  - Technical sales rep
  - Product engineering expert
  - Competitive analysis



Technical Manager

- **Technical Manager**
- **Planner, Scheduler, and Tracker of Technical Tasks**
- **Owner of Risk Management Plan**
- **Product Manager**
- **Product Engineer**



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Information Manager

- **Configuration Management**
- **Data Management**
- **Metrics**

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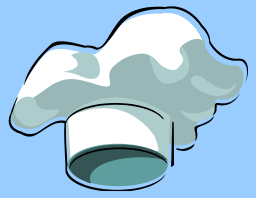
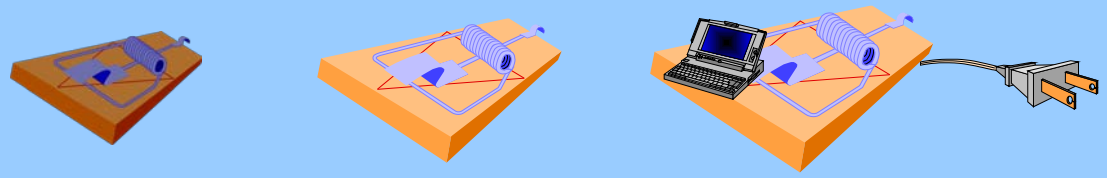


Process Engineer

- **Process Engineer**
- **Business Process Reengineer or Business Analyst**
- **Owner of the Systems Engineering Process**
- **Attention to enterprise needs rather than to needs of individual systems and customers – *product lines***



Coordinator

- **Coordinator of the Disciplines**
- **Tiger Team Head**
- **Head of Integrated Product Teams (IPTs)**
- **System Issue Resolver**

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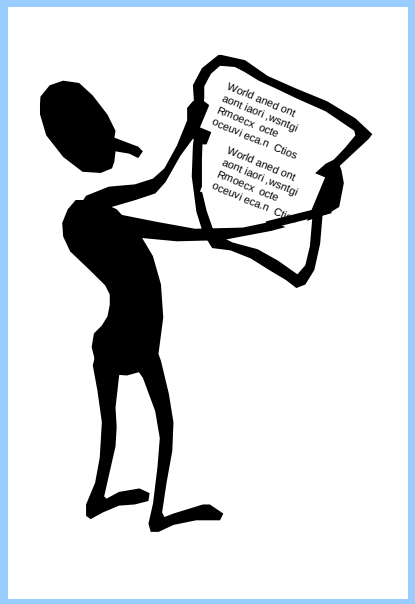
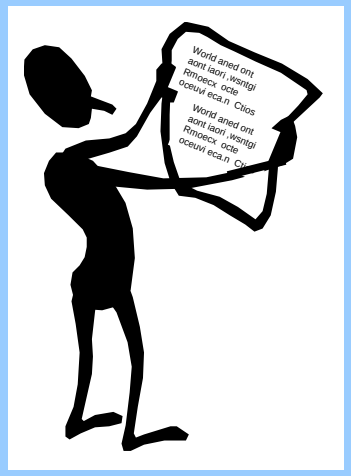
Classified Ads Systems Engineer



- **“Skills must include shell scripting, SQL, performance analysis, and network integration.”**
- **“...five years of solid analytical & debugging expertise in a telecommunications environment”**
- **“Analyze and develop systems level software in C/C++ and UNIX scripts.”**

Classified Ads Systems Engineer, cont'd



- **"Object-Oriented/Design/Analysis/ Programming... RDBMS (Oracle), ...CICS/PLI, ...STAIRS/ Search Manager..."**
- **"Provide UNIX Administration and service delivery for our ... Internet service"**
- **"Provide design, implementation, and ongoing support for Managed and Non-Managed Private X.25, Frame Relay, and ATM Networks…"**

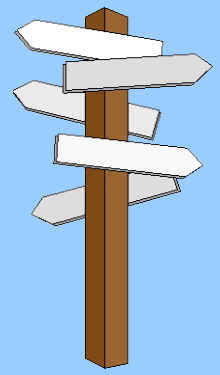
Not considered basic SE role; included to show that there are still other definitions.

The Roles in INCOSE Papers

Role / Reference	1 RO	2 SD	3 SA	4 VV	5 LO	6 G	7 CI	8 TM	9 IM	10 PE	11 CO
Bahill 94		▲	✓								
Beam 94	✓	✓	✓	✓	✓	✓					
Blanchard 94	✓	✓		✓	✓	✓					✓
Boehm 94		▲	▲			▲					
Dick 94	✓		▲				✓			✓	
Fabrycky 94	✓	✓	▲	▲							
Friedman 94	✓		✓	✓	✓	✓		✓	✓	✓	
Grady 94	✓	✓	✓			▲	✓	✓		✓	
Hatley 94	▲	▲	▲								
Lacy 94	✓							▲		▲	
Lake 94	▲	✓	✓	▲	✓	✓	✓	✓	✓		✓
Mar 94	▲	▲	✓	▲				✓	▲		
Rechtin 94		▲	✓			✓	▲				
Sage 94	✓	✓	✓					✓	✓	▲	
Wymore 94	✓	✓	✓	✓	✓						
Bate 95 (SE-CMM)	▲	▲	▲	▲		▲	✓	▲	✓	✓	▲
CAWG 95 (SECAM)	▲	▲	▲	▲		✓		▲	✓	▲	▲
DSMC 90	▲		✓	▲	▲	▲		▲	✓		✓
Matty 95	▲	▲					✓	▲			▲
McKinney 95	▲	✓	▲			▲			✓		✓
Sheard 95	▲	✓		▲		▲	▲	✓			▲

▲=Primary assumption, ✓=Secondary Assumption

Twelve Roles Conclusions



- **No two authors agree**
- **Most roles are controversial as to whether they are systems engineering roles**
- **“Systems Engineering” may mean any or all of the roles – clarify what you mean**

Unintentionally:

- **A systems engineering capability may be defined by determining who performs each of these roles**

What's Missing?

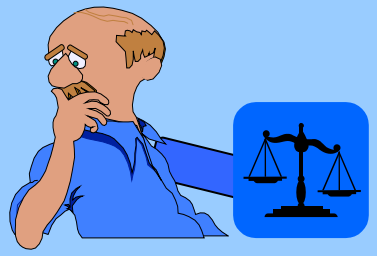
- What roles are important for which systems engineering tasks?
- Is systems engineering a process or an overarching function? a group or an approach?
- Is systems engineering mostly analysis and determination of measures of effectiveness, or does it include program coordination?
- How do you use standards and capability models to implement systems engineering?
- What kind of systems engineering research is needed?

Three Types of SE Implementations

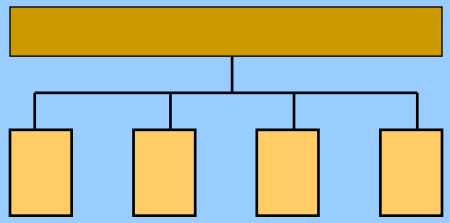
- Again attempting to understand extremes
- What differences there are between concepts of “systems engineering”
  - Generally becomes “aspects” of any real SE job as opposed to a hard distinction
- Note where the polarities of SE apply (what is “the discipline” vs “the generalist, etc.)

Three Types of Systems Engineering Implementation

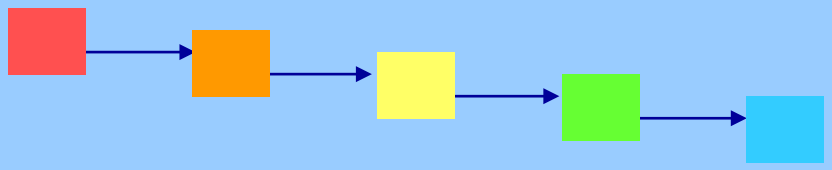
- ***Discovery***



- ***Program Systems Engineering***



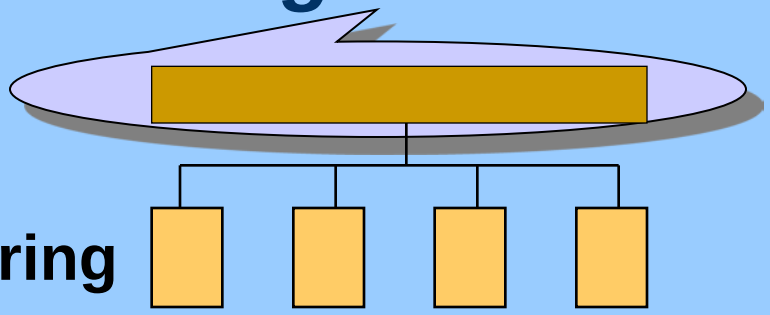
- ***Approach***



Discovery

- **Focus on determining whether a feasible solution exists**
- **Concept exploration and Definition (phases A&B)**
- **Systems engineers are analysts investigating unprecedented problems**
- **Very high complexity in problem space**
- **“Specialists in the SE Discipline”**
- **Examples: Atlas rocket, SAGE computer system, Boston Central Artery/Tunnel**

Program Systems Engineering



- **Systems engineering is the group responsible for engineering the top level system**
  - **Good SEing involves many other people**
- **Focus on solution space and building it competitively. Complexity in solution and organization.**
- **Precedented problems, new solutions**
- **Generalists**
- **Technical side of program management, coordinator**

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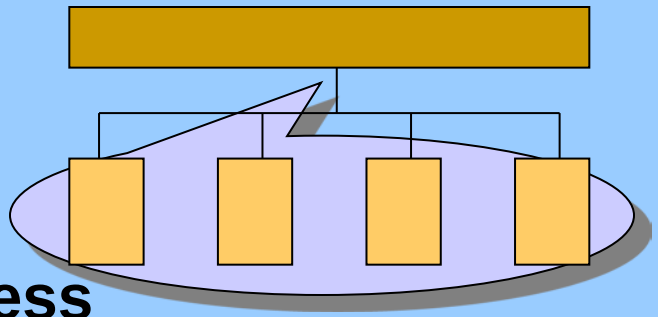
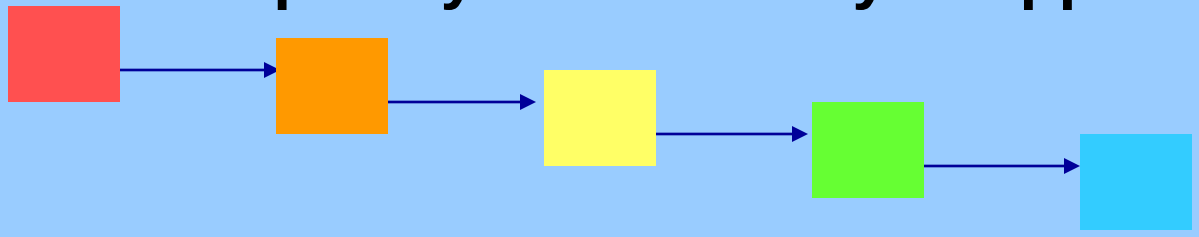
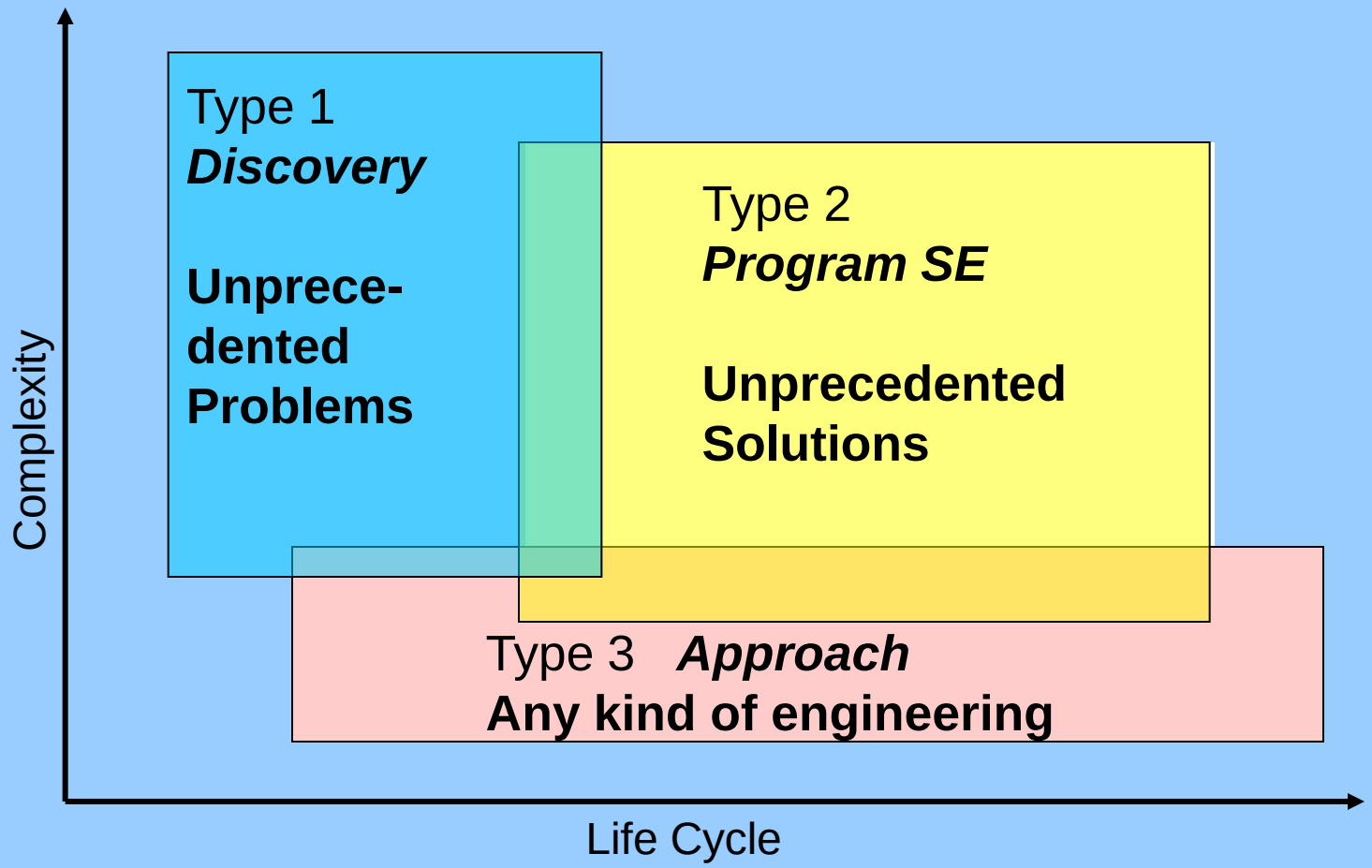
Approach



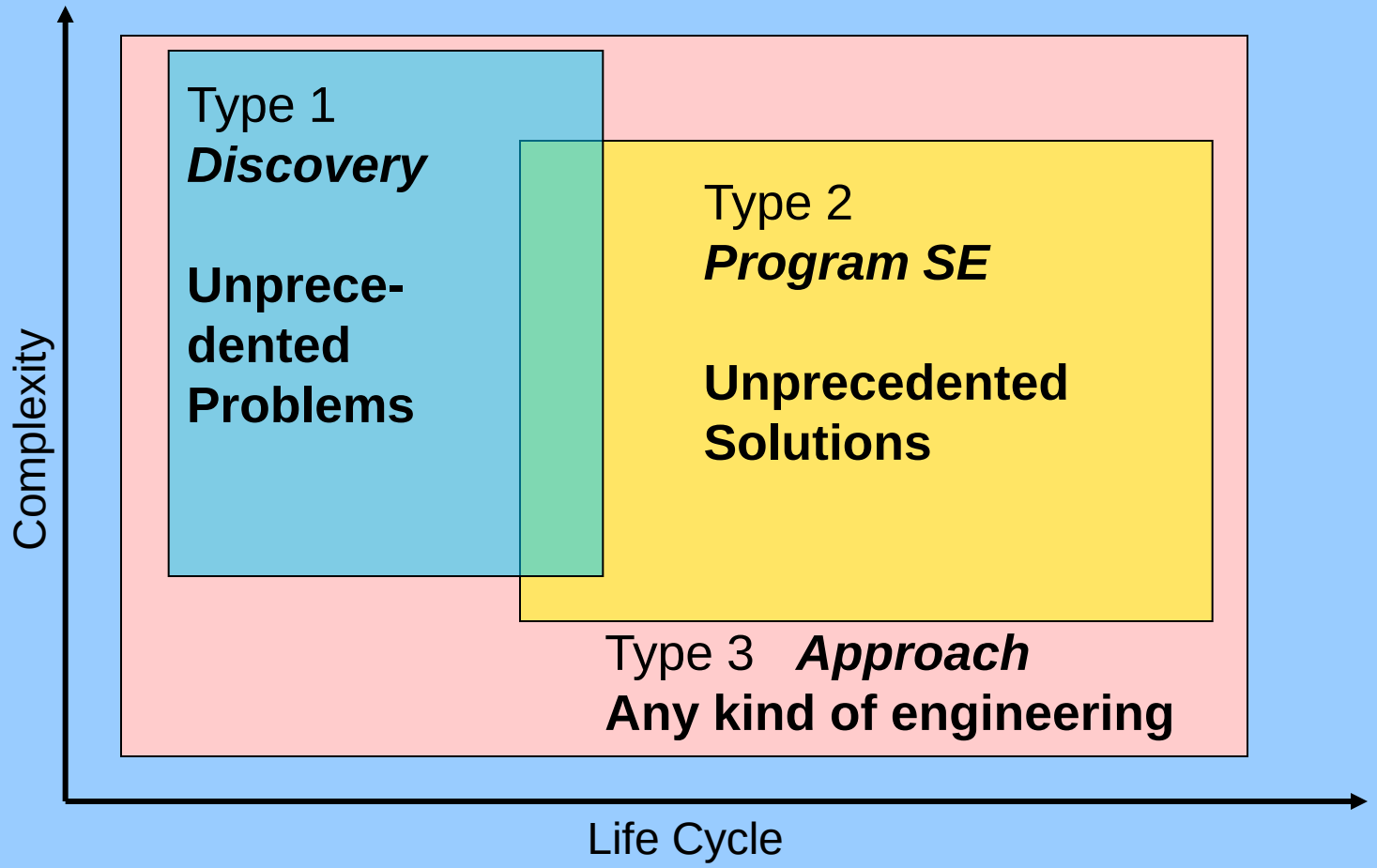
- The Systems Engineering Process
- What every engineer should do
- Focus on applying life cycle steps to any project and task
  - Setting up a colloquium talk
  - Developing a requirements document
- Problem solving using the scientific method
- Complexity in the variety of applications



Three Types (in paper)



Three Types


Type 1
Discovery
Unprece-dented Problems
Type 2
Program SE
Unprecedented Solutions
Type 3 *Approach*
Any kind of engineering
Complexity
Life Cycle

Systems Engineering Standards

Discovery	**None very applicable**
Program Systems Engineering	**EIA 632, IEEE 1220, EIA/IS 731**
Approach	**IEEE 1220 EIA/IS 731 (tailored)**

If we do this can we answer…

- Is systems engineering a process or an overarching function? a group or an approach?
- Is systems engineering mostly analysis and determination of measures of effectiveness, or does it include program coordination?
- How do you use standards and capability models to implement systems engineering?
- What kind of systems engineering research is needed?

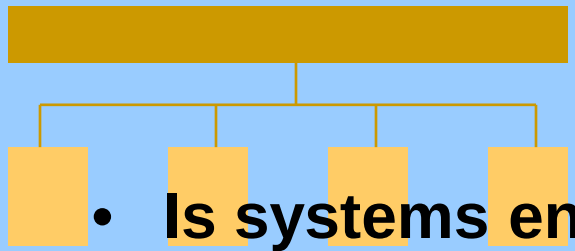
Examples

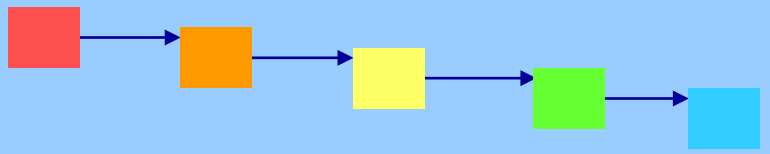
	Discovery	Program Systems Engineering	Approach
Tools	Analysis, simulation, modeling	Templates for processes; requirement mgt; office tools	None specific to doing a task with the system in mind particular
Research	Analysis quality and applicability	Process cost effectiveness Coordination of best practices	Benefits of implementation Education

What Systems Engineering Do We Need?

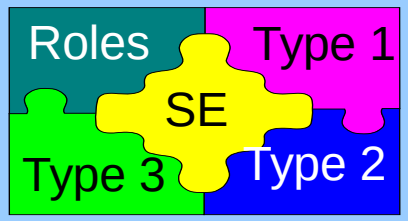
- **Systems engineering is both an umbrella function over software and other disciplines, and a necessary part of any product development process**
  - **Discovery is analysis-intensive; needed early to understand a complex problem space**
  - **Program systems engineering realizes design**
  - **Approach is needed for all tasks**
- **Systems engineering must involve others to create future systems that work**
  - **Determine who will perform what roles, when, and how**

Can we answer these?





- **Is systems engineering the engineering of the top-level system, or a process?**
- **Are systems engineers specialists or generalists?**
- **Are systems engineers some people or all engineers?**
- **Do standards and capability models describe systems engineering well?**



Summary

- **Agree that systems engineering consists of the sum of pieces**
  - **Roles**
  - **Types of implementation**
- **Clarify “Systems Engineering”**
- **Present a united front that systems must be engineered**
  - **Top level systems require *Program Systems Engineering***
  - **All disciplines need *Approach***

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Roles and Types

Discovery	**SA, RO, IM, TM**
Program Systems Engineering	**SD, CO, CI, G, VV, RO**
Approach	**RO, SD, VV, LO, CI, TM**

Role Combinations and Capability Models

- **Life Cycle Roles – RO, SD, (SA), VV, LO**
  - **Technical focus areas**
- **Program Management Roles – TM, G, IM, CO, (CI)**
  - **Management focus areas**
- **Risk – G, SA, TM – Manage Risk**
- **Design Reviews – TM, CI, G – Monitor and Control**
- **Quality Assurance – PE, TM – Ensure Quality**

EIA/IS 731 (SECM) Focus Areas

Technical	Management	Environment
1.1 Define Stakeholder and System Level Requirements 1.2 Define Technical Problem 1.3 Define Solution 1.4 Assess and Select 1.5 Integrate System 1.6 Verify System 1.7 Validate System	2.1 Plan and Organize 2.2 Monitor and Control 2.3 Integrate Disciplines 2.4 Coordinate with Suppliers 2.5 Manage Risk 2.6 Manage Data 2.7 Manage Configurations 2.8 Ensure Quality	3.1 Define and Improve the Systems Engineering Process 3.2 Manage Competency 3.3 Manage Technology 3.4 Manage SE Support Environment

Use Example: 12 Roles and Organizational Processes